VALIDATION OF REAL TIME DISPERSION OF TRITIUM OVER THE WESTERN MEDITERRANEAN BASIN IN DIFFERENT ASSESMENTS

P.Castro[1], M.Velarde[2], J. Ardao[3], M.Perlado[2], L.A.Sedano[1]

[1]*EURATOM-CIEMAT Association, LNF: Fusion Technology Division, Breeding Blanket Technologies Unit, 28040-Madrid, Spain,* paloma.castro@ciemat.es*;* luis.sedano@ciemat.es
[2]*UPM_ETSII Nuclear Fusion Institute: DENIM, Madrid, Spain,* mvelam@denim.upm.es; josemanuel.perlado@upm.es
[3]*MIMAM: Agencia Estatal de Meteorología, 28040 Madrid, Spain.* jardaob@aemet.es

Real time Tritium concentrations in air coming from an ITER-like reactor as source were coupled the European Centre Medium Range Weather Forecast (ECMWF) numerical model with the lagrangian atmospheric dispersion model FLEXPART. This tool ECMWF/FLEXPART was analyzed in normal operating conditions in the Western Mediterranean Basin during 45 days at summer 2010. From comparison with NORMTRI plumes over Western Mediterranean Basin [1] the real time results have demonstrated an overestimation of the corresponding climatologically sequence Tritium concentrations in air outputs, at several distances from the reactor. For these purpose two clouds development patterns were established. The first one was following a cyclonic circulation over the Mediterranean Sea and the second one was based in the cloud delivered over the Interior of the Iberian Peninsula by another stabilized circulation corresponding to a High. One of the important remaining activities defined then, was the tool qualification. The aim of this paper is to present the ECMWF/FLEXPART products confronted with Tritium concentration in air data. For this purpose a database to develop and validate ECMWF/FLEXPART tritium in both assessments has been selected from a NORMTRI run. Similarities and differences, underestimation and overestimation with NORMTRI will allow for refinement in some features of ECMWF/FLEXPART.

I. INTRODUCTION: NORMTRI AND ECMWF/FLEXPART MODEL

The objective of this paper is to make a useful and simple validation of the Lagrangian Atmospheric coupled ECMWF/FLEXPART model applied to atmospheric tritium, (Ref. 1,2). This validation is already a comparison of the values of maximum concentration of both different chemical forms HT and HTO, obtained with two different models, in certain defined radial spaces or special bands, with the NORMTRI model in the surroundings of Vandellós. For ECMWF/FLEXPART we have formed a new data base of both chemical forms of atmospheric tritium HT and HTO, from the 1st of October 2010 until the 31st of March 2011.

I.A. Point of emission, levels in air and source term

We assume major concentration activity of the tritiated species should be in the very low levels. Therefore we have selected 10, 30 and 60 meters for obtaining ECMWF/FLEXPART products of the emission release of tritium (when in continuous displacement in the boundary layer), (Ref. 3). The source term is placed in Vandellós, this is considered the point of release in routine. Fictitious exaggerated tritium sources of about 2.7 mg of tritium per event-day (~ 25 Ci/event-d) in HT form (e.g. emitted 3.65 mg of HT) or 0.27 mg (~ 2.5 Ci/event-d) of tritium per event-day in HTO (e.g. emitted: 1.8 mg of HTO) (Ref. 3). The dispersion of atmospheric tritium can be very different, as a function of the water vapor tritiated clouds development and movement (stratified or convective, horizontal or with vertical ascendant or descendent air currents). In order to compare the tritium concentrations in air taken by both models, we will compare the same source term in both models. This has been verified both for NORMTRI and ECMWF/FLEXPART outputs different for HT. For example the 3 "weather sequences" in NORMTRI ranges for a total of 66,9 TBq (for HT) and the source term in ECMWF/FLEXPART is around 0,0027 g/day. Therefore both are really the same in both NORMTRI and ECMWF/FLEXPART numerical models.

I.A.1. ECMWF/FLEXPART

On one hand FLEXPART is a Lagrangian Model of atmospheric contaminants, here adapted in both chemical forms of atmospheric tritium, using as input data the outputs of the numerical weather prediction model of the European Center for Medium Range Weather Forecast. As the numerical ECMWF model has 91 levels in the vertical of the atmosphere (an an horizontal resolution of

50 km in the horizontal) the coupled ECMWF/FLEXPART became a proposed tool to better describe the variability of weather behavior (taking into account in instance the wind, not only near the ground, but also in all vertical levels of the atmosphere, from the boundary layer to the troposphere and the stratosphere).

In this paper we have made a new HT/HTO data base by using the short range forecast from 3 to 24 hours, with a frequency of 3 hours. The area of interest should be synoptic, mesoescalar or local. In our case ECMWF/FLEXPART we have selected the (meso) area ranging from 38ºN 1º 27´W to 43º N 7º 38º E allowing us for the evaluation of tritiated plumes/clouds into this particular area over the Mediterranean Sea. (Ref.4)

It is important to understand FLEXPART uses as input all surface and height observations of temperature, humidity, precipitation and wind speed and wind direction that are required in the analysis for first guess of the model fields of those variables (allowing for forecasting in real time).. It already gives some products concerning depositions in soil (dry and wet).

I.A.2 Computer Simulation

On the other hand NORMTRI has been developed to calculate the behavior of tritium in the environment released into the atmosphere under normal operation of nuclear facilities. NORMTRI is based on the statistical Gaussian dispersion model ISOLA, which calculate the activity concentration in air near on the surface contamination due to dry and wet deposition at specified locations in a polar grid system. ISOLA requires a different parametric meteorological statistics derived from one year local synoptic recordings (at Vandellos, with determined frequency: of 1 hour averages of wind speed, wind direction, stability class and precipitation intensity. The great value of NORMTRI opens the possibility to choose several dose calculations procedures ranging from the equations of the European regulatory guidelines based in a equilibrium approach. NORMTRI is applied to radial zones centered in Vandellós. Concerning the 3 Weather (climatological) sequences used by NORMTRI, they are the followin: first sequence: winter period from the first of January to 31 March; second period called vegetable (growing) period, ranges from April 1 to October the 15th; third period: start on October 16 ending by December 31st (Ref. 5,6,7). The reemission periods (after plume passage over soil and "reflexion") in NORMTRI for HT is 144 hours; for HTO is 70 hours. Soil has 4 layers, but reemission in the soil layer is produced from 0 to 5 cm of depth. The area for verification can be different of the Grid of Gaussian Model NORMTRI. We decide to select a radial special area centered in Vandellós Fusion Plant and execution of models is reviewed by specific zones for validation. NORMTRI has been used for dose predictions due to a one hour ground level (30 m) atmospheric release of tritium as HT and as tritiated water.

II. VALIDATION OF ECMWF/FLEXPART TRITIUM ATMOSPHERIC CONCENTRATION. OPERATIONAL ZONES FOR VALIDATION WITH NORMTRI

As concerns a simple establishment of zones to validate concentrations of HT or HTO modeled we have taken the advantage of the Spanish Management Plan for Nuclear emergencies PENTA definition of Emergency Planning Zones (EPZ) (Ref.8).

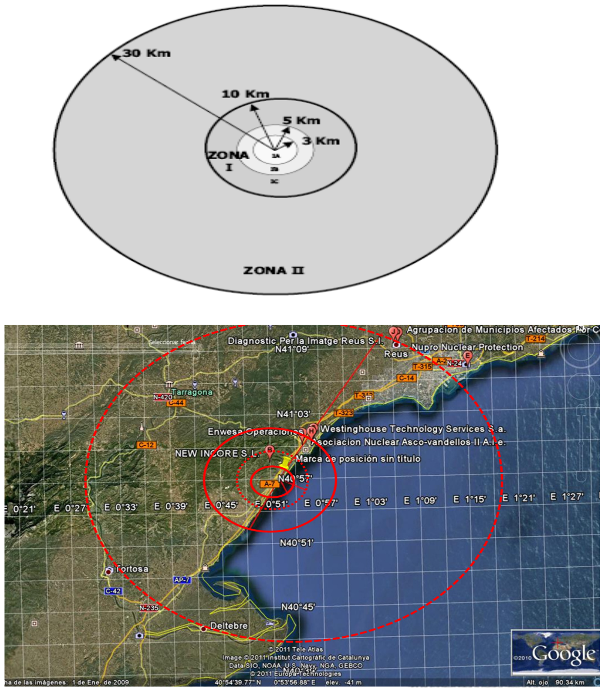


Fig. 1. Validation of tritium dispersion to be done in radial zones following "PENTA-CSN regulation" for EPZ Vandellós [Ref.7]. On the other hand tritiated clouds in ECMWF/FLEXPART area (selected from 38ºN 1º 27´W to 43º N 7º 38ºE).

In figure 1 we represent the Radial zones for validation of tritium dispersion with NORMTRI (Ref.9). Radial zones follow PENTA CSN regulation for Vandellós and initially can be considered as EPZ. Tritium should be dispersed both into the interior of Iberian Peninsula and downwind into the West Mediterranean basin. What we are looking for is the value of atmospheric tritium (E.g. range of concentrations from the interior or each ring to the outer part of the band, e.g. in a part of the zone I or in the zone II). We already are looking for both HT and HTO concentrations in the height level of 30 m taken by NORMTRI and ECMWF/FLEXTRA models in order to make a comparison between correspondently values to

each model. We will test if they are in the same order of magnitude or – in the contrary - NORMTRI may overestimate or underestimate the ECMWF/FLEXTRA atmospheric tritium forecast in the first 24 hours. As NORMTRI is working in three weather sequences (at least one year of weather observations data in surface: pressure, humidity, wind and temperature) we try to make a significant comparison of models, (Ref. 9). It has to be made, mainly but not only, in terms of a number of runs ejected of the Lagrangian atmospheric dispersion model for the corresponding HT and HTO well defined atmospheric tritium /in the form of plumes or clouds).
We can consider the conceptual release of effluents of Tritium into the Atmosphere during normal operation condition. with Fictitious exaggerated tritium sources of about 2.7 mg of tritium per event-day (~ 25 Ci/event-d) in HT form (e.g. emitted 3.65 mg of HT) or 0.27 mg (~ 2.5 Ci/event-d) of tritium per event-day in HTO (in instance emitted: 1.8 mg of HTO).

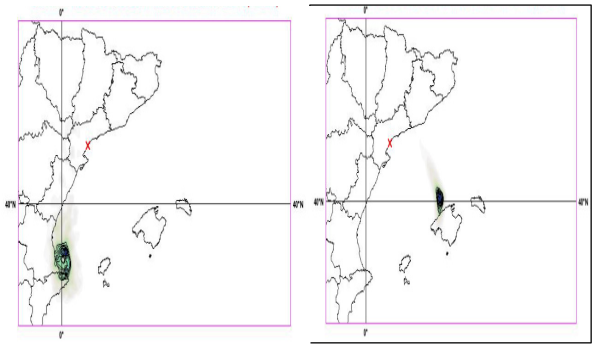


Fig. 2. Tritium cloud moving to the South following a mesoescale wind cyclonic atmospheric circulation on the 19th of March 2011.

In figure 2 an example of this movement is shown. Tritium cloud is being moved by wind to the South following a mesoescale cyclonic atmospheric circulation. Therefore HT cloud is first in front of Palma de Mallorca and later it can be observed into the Gulf of Valencia during the 19th of March 2011.The ECMWF/FLEXPART run executed is able to manage the transport of these effluents giving the detail of atmospheric tritium with a frequency of 3 hours, in the short range. We have elaborated a significant sample or data base of HT and HTO "ECMWF/FLEXPART products" corresponding to winter 2010 and spring 2011. The input data comes from Reading (UK) where it is placed the European Centre for Medium Range Weather Forecast. Spanish Meteorological Agency –actually called AEMET- has a real time direct access to required forecast fields. Then coupled ECMWF/FLEXPART products already contain information on the latitude and longitude of the maximum concentrations of the cloud. Those products now represent the lagrangian transport of tritiated species (elemental gas HT and tritiated water) and the movement of the clouds or plumes downwind.

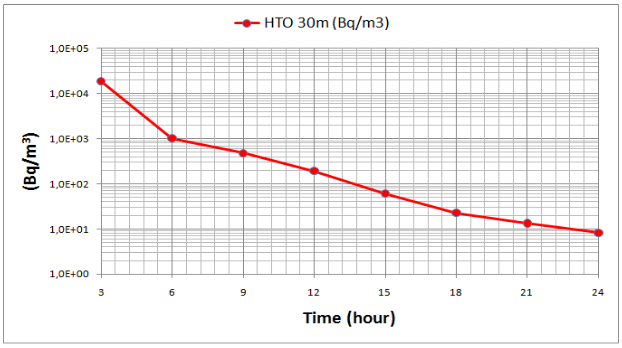


Fig 3. One of the two different representations of ECMWF/FLEXPART. Atmospheric HTO Forecast evolution.

ECMWF/FLEXPART products in figure 3, shows an example of transported HT. We made a conceptual decision established –in the new data base- 4 different types of tritiated patterns (see table 1) and just worked with the most significant **cases** into the classification. (With a total of around 30 days summarizing classified cases). We already excluded the assessments of clouds downwind with tritium delivery by the interior of Iberian Peninsula or Europe.
During winter 2010 and spring 2011 the great number of cases with the maximum concentrations have been found correspondent to clouds moving over the Mediterranean Sea (atmospheric cyclonic and anticyclonic circulations) in a stationary or slow movement towards Valencia (or Castellón and Alicante, following so called pattern type B). They had wind speeds less than 20 Km/h or 5,5 m/s). The days included in the case B (stationary cloud or slow movement to the South, were the following: 3, 10, 12, 15, 18 and 20 of January and the 3rd and 26th of February and finally the 19th of March.

III. NORMTRI VALIDATION OF ATMOSPHERIC TRITIUM IN BOTH CHEMICAL FORMS, AT PENTA ZONES.

Into the PENTA Zones 0, I, II (figure 1) a range of significant HT and HTO concentration values have been obtained by NORMTRI and ECMWFLE/FLEXPART (when ECMWF resolution permits). The forecast outputs and the results of atmospheric tritium (at the level of 30 m) are summarized in table II, where the values of NORMTRI and ECMWF/FEXPART atmospheric tritium concentration outputs are presented into the PENTA-Vandellós EMZ. In both models Forecast HT, HTO values corresponds to the concentrations at level of 30 m, over the innermost/closest available result to first boundary of the band; and over the outermost radius (the closest available output to the outermost boundary), within zones 0, I and II. As ECMWF/FLEXTRA has 50 Km of horizontal resolution, some values in zone I cannot be available (if they are under that resolution).

TABLE I. Simple classification of atmospheric tritium in 4 tritiated cloud types (patterns) as a function of plume passage or distance of its transport in air. This allows for a reduction of the 6 months data base to the most significant cases obtained with ECMWF/FLEXPART.

Patterm	Transport plume distance (Km)	Magnitud order range HT (Bq/m^3)	Tendency HT reduction	Observed 10m wind (km/h)
A-Stationary Plume to North	0 < R < 100 km Local to mesoscale	6-3	Caotic fashion ruduction	CALM OR VERY LIGHT 0 < v < 5 km/h
B-Stationary plume to the South	0 < R <100 Km Mesocale transport	3-6	No Reduction (& orographic effects Ijust in coast)	LIGHT 0 < v < 20 km/h
C-Fast displacement plume+ Vortex by orography	100 < R < 200 Km Large transport distance (in mesoescale)	6-2	Quasi lineal reduction	MODERATE 20 < v < 50 Km/h

To summarize NORMTRI overestimates in 3 orders of magnitude HT atmospheric concentration in the area close to reactor. The difference is reduced to 1 order of magnitude from 10 km in advance. When distance from the reactor is more than 100 Km, then both models gives atmospheric tritium within the same order of magnitude. Ratios from NORMTRI to ECMWF/FLEXPART values by chemical form of shows NORMTRI overestimates in 3 orders of magnitude close to the reactor up to 10 km.

To summarize: Close to the reactor – in the PENTA zone 0- NORMTRI overestimates the ECMWF/FLEXPART. In particular the HTO is overestimated by 3 orders of magnitude. In the band up to 10 km (750 m < R < 10 Km) NORMTRI already presents an overestimation of 2 orders of magnitude for atmospheric HT and 3 orders of magnitude in the atmospheric HTO. Differences are drastically reduced to achieve 1 order of magnitude or less at 100 Km.

IV. NORMTRI OVERSTIMATION OF ECMWF/FLEXPART TRITIUM STATIONARY CLOUDS TYPE B AT LEVEL 30 METRES

This overestimation, from 10 km and major distances the difference is reduced. Finally at 100 km both NORMTRI and real time observations runs in the same order of magnitudes. To summarize, at large distances HT and HTO is similar in both models. At short distances, close the emission point (EMZ Penta-0), HT and HTO are

TABLE II. Atmospheric tritium outputs of NORMTRI and ECMWF/FEXPART into the different zones. Forecast HT, HTO values correspondent concentrations in air –at 30 m - over the innermost/outermost radius, within EMZ PENTA- zones 0, I and II.

Ranges (Bq/m^3)	r_0(m)	R < 750 m (PENTA ZONE 0)	r_{I1}(m)	750 m < R < 10 Km (PENTA ZONE I)	r_{I2}(m)	10 km < R < 30 Km (PENTA ZONE II)	r_{I3}(m)	30 Km < R < 100 Km
HT NORMTRI	IN: OUT:	2,4E+08 1,3E+08	OUT: IN:	7,4E+07 1,5E+06	OUT: IN:	1,5E+06 4,2E+05	OUT: IN:	4,2E+05 1,3E+05
HTO NORMTRI	IN: OUT :	2,4E+08 1,3E+08	OUT : IN:	7,6E+07 1,8E+06	OUT : IN:	1,9E+06 5,2E+05	OUT : IN:	5,2E+05 1,7E+05
HT ECMWF-FLEXTRA (Hor. Res ECMWF 50 km)	IN: OUT:	4,6E+05 1,7E+05	OUT: IN :	N/A N/A	OUT: IN :	 1,1E+04	OUT: IN :	6,9E+03 4,3E+03
HTO ECMWF-FLEXTRA (Hor, res ECMWF50 Km)	IN : OUT :	1,8E+04 2,2E+04	OUT :	N/A N/A	OUT :	 3,5E+02	OUT :	4,1E+02 5,8E+02

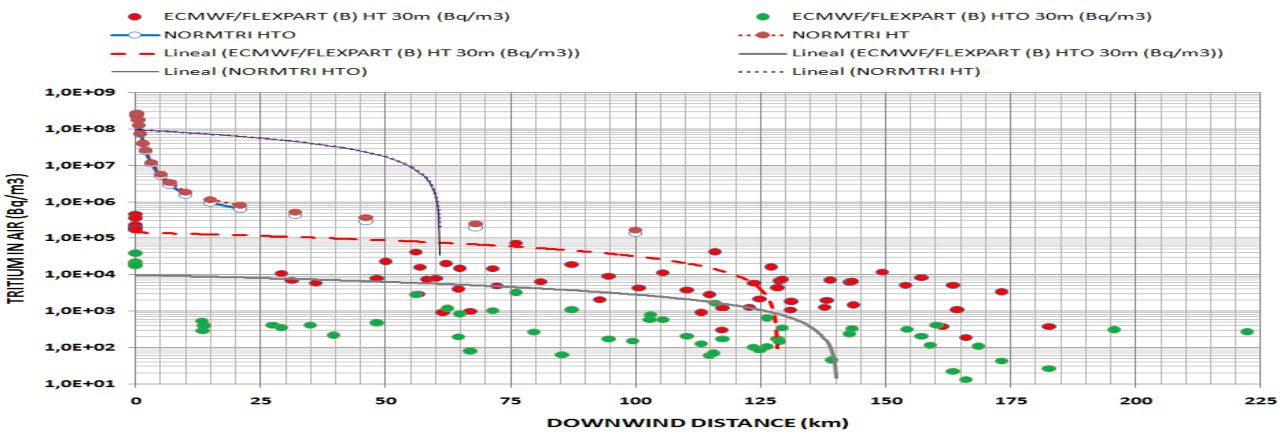


Fig. 4. NORMTRI overestimates ECMWF_FLEXTRA values. NORMTRI can evaluate concentrations up to 100 Km. For far distances ECMWF_FLEXTRA give real time values. At all cases under the value of HT and HTO concentrations in air at 100 km: 1,3E+5 Bq/m^3 for HT and 1,7E+5 Bq/m^3

overestimated in 3 orders of magnitude. The validation in terms of both models comparison has been represented in figure 4.

V. EDES UNDER PENTA-LEVEL-3 REQUIREMENTS FOR PRECAUTIONARY MEASURES

Finally, by following test cases (100% HT and 100% HTO) for ITER-Vandellos at 30 m we have represented contribution of exposure pathways to EDE. Taking into account PENTA urgent actions (those to be adopted in a fast way in order to be efficient, otherwise their efficiency –concerning population health- would be significantly decreased) that would be applied during a short period of time. Within those urgent precautionary measures there are mainly three; confinement, radiological prophylaxis and evacuation.

To summarize the question is: Can fusion routine delivery of tritium in atmosphere produce effective doses over 10 mSv (and therefore confinement should be taken into account)? Similarly can fusion routine delivery of tritium in atmosphere produce effective doses over 100 mSv (and therefore radiation prophylaxis (tiroides) should be taken into account? NORMTRI study case results with contributions of exposure pathways to EDE have been obtained and they are represented in figure 5 for both chemical tritium forms.
In figure 6 we represent some values in correspondent PENTA ZONES, all values are less than 10 mSv (and under 1 mSv the ITER limit in the French regulation). Therefore the answers to our questions are negative, in other words at all radial distances the precautionary PENTA measurements, both for confinement, both for prophylaxis, in those emergency planning zones (EPZ) are not required. This is due the correspondent doses are under the regulatory limits.

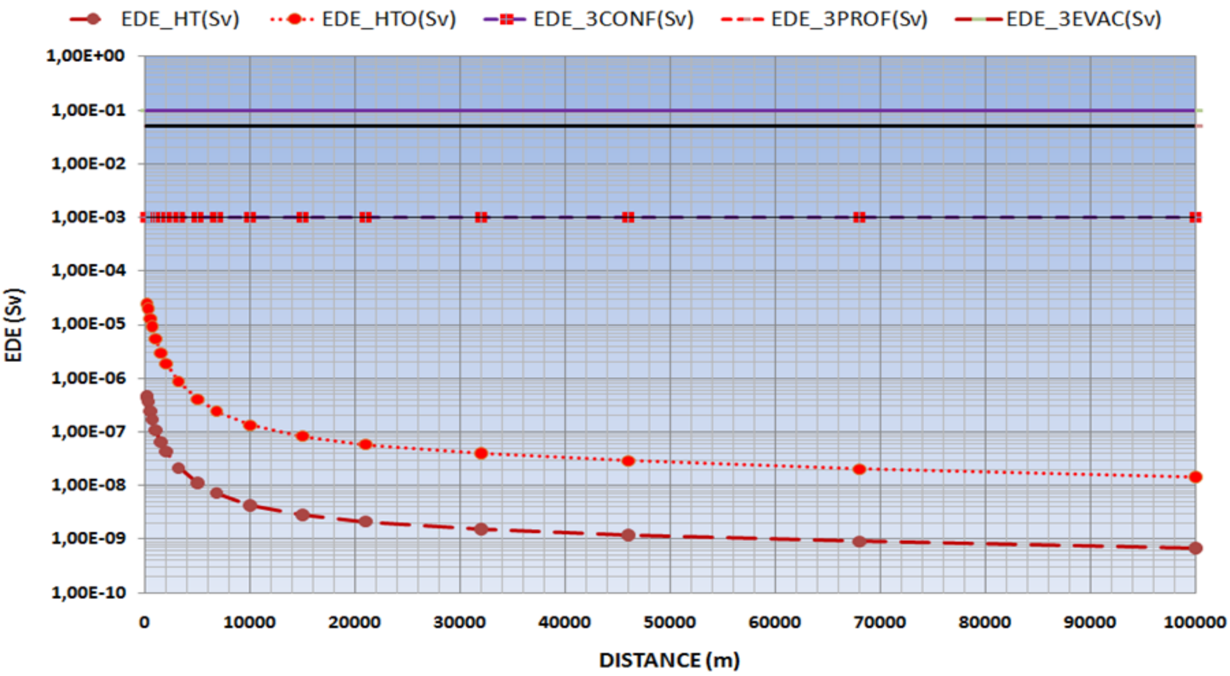


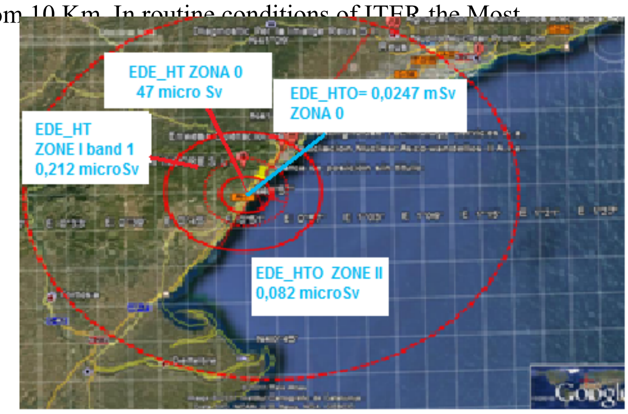
Fig. 5. Effective Dose (EDE) from NORMTRI study case.

Other complementary measures should be the control of accesses, and personal protection, confinement of animals and personal decontamination. We are just interested in those levels of intervention for urgent precautionary measurement, and not in those for long term (Ref.10, 11, 12).
NORMTRI executed for ITER reactor tritium effluents HT/HTO at 30 level in routine, has given Effective Dose (EDE) by contribution of exposure pathways (percentage of inhalation, percentage of ingestion; and percentage of inhalation due reemission (figure 5).

VI. CONCLUSSIONS

At large distances HT and HTO are similar in both models. At short distances, close the emission point, HT and HTO concentrations are overestimated. HTO is overestimated in 3 orders of magnitude; HT is overestimated 2 orders of magnitude. Therefore there is a big difference between both models at short distances.
ECMWF/FLEXPART HT/HTO real time concentrations of atmospheric tritium are under NORMTRI HT/HTO

maximum concentrations in air. NORMTRI can be used from 10 Km. In routine conditions of ITER the Most



R(m)	EDE_HT(Sv)	R(m)	EDE_HTO(Sv)
145	4,73E-07	145	2,47E-05
210	4,41E-07	210	2,45E-05
320	3,65E-07	320	2,00E-05
500	2,47E-07	500	1,32E-05
680	1,73E-07	680	9,23E-06
1000	1,08E-07	1000	5,49E-06
1500	6,40E-08	1500	2,99E-06
2000	4,25E-08	2000	1,88E-06
3200	2,12E-08	3200	8,67E-07
5000	1,12E-08	5000	4,10E-07
6800	7,20E-09	6800	2,43E-07
10000	4,25E-09	10000	1,33E-07
15000	2,83E-09	15000	8,27E-08
21000	2,12E-09	21000	5,86E-08
32000	1,54E-09	32000	3,99E-08

Fig. 6. Examples of EDE (Sv) for zones 0, I and II with indication of some values.

Exposed Individual (MEI) remains under the defined values into the protocol PENTA as precautionary measurements. Therefore, in level 3, EDEs remain under the threshold values for a possible confinement in the exclusion zone (Zone 0).

REFERENCES

1. A.Persson, F. Grazzini "User Guide to ECMWF forecast products. Version 4.0, 14-march 2007.
2. A. Stohl, C et al. Technical note: The Lagrangian particle dispersion model FLEXPART version 6.2. Norwegian Institute of Air Research, Kjeller, Norway. Organization, Vienna, Austria. Manuscript version from 21 April 2005.
3. P. Castro, M. Velarde, J. Ardao, J. M. Perlado, L. Sedano "Consequences of different meteorological scenarios in the environmental impact assessment of tritium release" 2P01-09," Book of Abstracts 9th International Conference on Tritium Science and Technology. TRITIUM 2010, October 24-29, 2010 Nara, Japan, FSD (2010).
4. D.Arnold, A.Vargas, M. Montero, A. Dvorzhak, P.Seibert. "Comparison of the dispersion model in RODOS-LX1 and MM5-V3.7-FLEXPART(V6.2). A case study for the nuclear power plant of Almaraz (Spain)". Croatian Meteorological Journal. HARMO 12, Vol.43, pp485-490, 2008 (ISSN: 1330-0083)
5. EU Scientific Seminar 2007 "Emerging Issues on Tritium and Low Energy Beta Emitters". Proceedings of a scientific seminar held in Luxembourg on 13 November 2007 Working Party on Research Implications on Health and Safety Standards of the Article 31 Group of experts.
6. M.Velarde, J. M. Perlado. "Tritium Dose Assessments under ITER accidental/normal Operational conditions for the European Candidate Site of Vandellós (Spain). April 2003. Contract EISS-Vandellós.
7. W. Raskob. NORMTRI, A Computer Program for assessing the Off_Site Consequences from Air-Borne Releases of Tritium during Normal Operation of Nuclear Facilities. Report KfK-5364. (1994).
8. Plan of Nuclear Emergency Exterior to Ascó and Vandellós (Tarragona). BOE 173. 21 Jul 2006.
9. W. Raskob, M. Velarde, J.M. Perlado, "Tritium Tritium Dose Assessments with Regulatory and Advanced Computer Models For The Potential European ITER Site Vandellós (Spain)", Fusion Science and Technology (2005).
10. Claudio Rizzello, Fabio Borgognoni, Tonio Pinna, Silvano Tosti,"Review of tritium confinement and atmosphere detritiation system in hot cells complex" Fusion Engineering and Design, Volume 85, Issue 1, January 2010, Pages 58-63.
11. Tritium release and dose consequences in Canada 2006. Part of tritium Studies Project. INFO-0793. Dec 2009. Canadá Nuclear Regulator. Canada Nuclear Safety Commision.
12. DOE Handbook, "Tritium Handling and Safe Storage". US. Department of Energy. Washington, D.C. 20585 (2008)